

10/018180  
JC05 Rec'd PCT/PTO 11 DEC 2007

[10191/2083]

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

Inventor(s) : Michael OFFENBERG et al.  
Serial No. : To Be Assigned  
Filed : Herewith  
For : MICROMECHANICAL COMPONENT AND  
CORRESPONDING MANUFACTURING METHOD  
Examiner : To Be Assigned  
Art Unit : To Be Assigned

Assistant Commissioner for Patents  
Washington, D.C. 20231

**PRELIMINARY AMENDMENT AND  
37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT**

S I R:

Kindly amend the above-captioned application before examination, as set forth below.

**IN THE SPECIFICATION AND ABSTRACT:**

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification (including the Abstract, but without claims) accompanies this response. It is respectfully requested that the Substitute Specification (including Abstract) be entered to replace the Specification of record.

**IN THE CLAIMS:**

On the first page of the claims, first line, change "What is claimed is:" to --WHAT IS CLAIMED IS--.

Please cancel, without prejudice, claims 1 to 9 in the underlying PCT application.

Please add the following new claims:

--10. (New) A micromechanical component, comprising:

a substrate;

a micromechanical functional plane provided on the substrate;

a covering plane provided on the micromechanical functional plane; and

a printed circuit trace plane provided on the covering plane;

wherein the covering plane includes a first monocrystalline region epitaxially grown on an underlying second monocrystalline region and a first polycrystalline region epitaxially grown on an underlying first polycrystalline starting layer at the same time.

11. (New) The micromechanical component according to claim 10, wherein the micromechanical functional plane includes the second monocrystalline epitaxially grown on an underlying third monocrystalline region and a second polycrystalline region epitaxially grown on an underlying second polycrystalline starting layer at the same time.

12. (New) The micromechanical component according to claim 10, wherein the micromechanical functional plane includes the second monocrystalline region, the second monocrystalline region including an SOI-type monocrystalline region formed above an insulator layer with the substrate.

13. (New) The micromechanical component according to claim 10, wherein the first monocrystalline region of the covering plane includes at least one of at least one integrated circuit element of an evaluation circuit and at least one wiring element.

14. (New) The micromechanical component according to claim 10, wherein a second polycrystalline region of the micromechanical functional plane includes a movable sensor structure.

15. (New) The micromechanical component according to claim 14, wherein the micromechanical functional plane includes a buried polysilicon layer underneath the movable sensor structure.



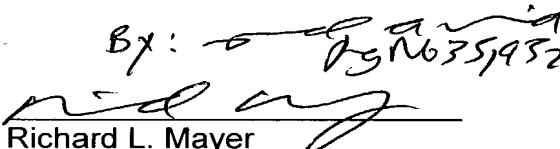
to correct informalities. As required by 37 C.F.R. §§ 1.121(b)(3)(iii) and 1.125(b)(2), a Marked Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/DE01/01116 includes an International Search Report, dated July 17, 2001, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

It is respectfully submitted that the subject matter of the present application is new, non-obvious and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully submitted,  
KENYON & KENYON

Dated: 12/11/01

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[10191/2083]

MICROMECHANICAL COMPONENT AND CORRESPONDING  
MANUFACTURING METHOD

FIELD OF THE INVENTION

The present invention relates to a micromechanical component including a substrate, a micromechanical functional plane provided on the substrate, a covering plane provided on the micromechanical functional plane, and a printed circuit trace plane provided on the covering plane. The present invention also relates to a corresponding manufacturing method.

BACKGROUND INFORMATION

Micromechanical function will be understood as an arbitrary active function, for example a sensor function, or passive function, for example a printed circuit trace function.

Although applicable to arbitrary micromechanical components and structure, in particular to sensors and actuators, the present invention and its underlying problem will be explained with reference to a micromechanical component, for example an acceleration sensor, which is manufacturable in the technology of silicon surface micromachining.

Monolithically integrated, surface-micromachined inertial sensors with movable structures affixed to a chip in an unprotected manner (analog devices) are generally known. These designs cause an increased expenditure of time and energy during handling and packaging.

These problems can be avoided using a sensor having an evaluation circuit on a separate chip; in this context, for example, the surface-micromachined structures are covered by a second cap wafer. This type of packaging composes a high portion of the cost of a surface-micromachined acceleration sensor. This cost results from the large surface required for the sealing surface between the cap wafer and the sensor wafer

and because of the complex patterning (2-3 masks, bulk micromachining) of the cap wafer.

The evaluation circuit is implemented on a second chip and connected to the sensor element via wire bonding. This, in turn, creates the necessity for the sensor elements to be sized such that the parasitic effects developing due to the parasites in the lead wires and bonding wires are negligible and that they no longer have any dominant influence on the sensor function. In addition, flip-chip techniques are ruled out because of parasitic effects.

Such sensors could use considerably less surface for the micromechanics if the evaluation circuit were situated on the same Si chip and the sensitive electrodes could be connected with only low parasities.

German Published Patent Application No. 195 37 814 describes the structure of a functional layer system and a method for the hermetically packaging of surface-micromachined sensors. Explained in this context is the manufacture of the sensor structure using known technological methods. The mentioned hermetical packaging is effected using a separate cap wafer which is made of silicon and patterned using complex patterning processes such as KHO etching. The cap wafer is affixed to the substrate featuring the sensor (sensor wafer) using a glass solder (seal glass). For this purpose, a broad bonding frame is required around each sensor chip to ensure sufficient adhesion and tightness of the cap. This considerably reduces the number of sensor chips per sensor wafer. Due to the large space required and the complex manufacture of the cap wafer, considerable costs are attributable to the sensor packaging.

German Published Patent Application No. 43 41 271 describes a micromechanical acceleration sensor whose components are composed partly of monocrystalline material and partly of

polycrystalline material. For manufacturing this micromechanical acceleration sensor, an epitaxial reactor is used. A starting layer made of LPCVD polysilicon is used for determining the regions where polycrystalline silicon is intended to grow during the epitaxial process.

# SUMMARY

The micromechanical component and the manufacturing method according to the present invention have several advantages. It is possible for the evaluation circuit and the sensor element to be monolithically integrated on one chip. Error-prone complex bonding wires between the sensor element and the evaluation circuit may be omitted. The size of the sensing elements may be reduced since less parasitic effects occur in the bonding. Only one chip has to be mounted. The process is based on the surface-micromachining process described in German Published Patent Application No. 43 18 466, which yields epitaxial polysilicon having a thickness of at least 10  $\mu\text{m}$ . A simplification of the surface-micromachining process is provided because the structures may be bonded from above. The buried polysilicon may be omitted.

The integration of the component is independent of the process of the evaluation circuit to the greatest possible extent. As a result, the adaptation to new IC processes is simplified. Depending on the sensor principle, the component may be reduced to the size of the bonding pads heretofore required on the IC for bonding, which results in the cost not increasing due to additional surface.

According to the present invention, the sensor chip may be connected using the so-called "flip-chip method", that is upside down with eutectic or gold bumps instead of using bonding wires, since the parasitic influences are strongly reduced in comparison with the two-chip solution. Using this technique, it is also possible to produce sensors with CSP (chip scale package), package of which is no more than 20%

larger than the chip. A CSP-packaged chip may be premeasured and trimmed prior to assembly.

The core of the present invention is the combination of the single-crystalline and polycrystalline growth during the deposition of the covering layer in the epitaxial reactor. In the process, single-crystalline silicon requires a single-crystalline surface as a starting layer, polycrystalline silicon requires a polycrystalline starting layer which may be deposited using LPCVD.

According to one example embodiment, a first layer featuring the micromechanical functional plane has a monocrystalline region which is epitaxially grown on the underlying monocrystalline region as well as a polycrystalline region which is epitaxially grown on the underlying polycrystalline starting layer at the same time. Thus, the same epitaxial step is used twice in two different planes.

According to another example embodiment, a first layer featuring the micromechanical functional plane has an SOI-type monocrystalline region formed above an insulator layer with the substrate. This has the advantage that the buried polysilicon layer may be omitted and that one epitaxial step is dropped. A single-crystalline, high-doped base silicon material may be used which is free of mechanical stress.

According to another example embodiment, the monocrystalline region includes a second layer which is deposited on the first layer and which features one or a plurality of integrated circuit elements of an evaluation circuit or wiring elements. In this manner, a so-called "monolithically integrated one-chip solution" may be attained.

According to another example embodiment, the polycrystalline region of the micromechanical functional plane features a movable sensor structure.



According to another example embodiment, the micromechanical functional plane features a buried polysilicon layer underneath the movable sensor structure.

According to another example embodiment, one or a plurality of flip-chip connection elements, e.g., gold bumps, are provided in the printed circuit trace plane. This is a rugged bonding type which is made possible by the substantially planar surface.

According to another example embodiment, the component may be manufactured by silicon surface micromachining.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic cross-sectional view of a micromechanical component according to a first example embodiment of the present invention.

Figures 2a and b are schematic cross-sectional views of the manufacturing steps of the micromechanical component illustrated in Figure 1.

Figure 3 is a schematic cross-sectional view of a micromechanical component according to a second example embodiment of the present invention.

#### DETAILED DESCRIPTION

In the Figures, identical or functionally identical components are denoted by the same reference symbols.

Figure 1 is a schematic cross-sectional view of a micromechanical component according to a first example embodiment of the present invention.

In Figure 1, 1 denotes a silicon substrate wafer, 2 a lower oxide, 3 buried polysilicon, 4 a contact hole in sacrificial oxide, 5 a sacrificial oxide, 6 a first starting

polysilicon, 7 a first single-crystalline silicon of epitaxy,  
 8 a first epitaxial polysilicon, 9 an insulating trench, 10 a  
 movable sensor structure, 11 a first refill oxide, 12 a  
 contact hole in refill oxide 11, 13 a second starting  
 5 polysilicon, 14 a second single-crystalline silicon of  
 epitaxy, 15 a second epitaxial polysilicon, 16 an electrical  
 and/or mechanical connecting element between the first and the  
 second epitaxial polysilicon, 17 a trench, 18 a second refill  
 oxide, 19 an oxide for insulating the printed circuit traces,  
 10 20 a cross connection, 21 a printed circuit trace, 22 a  
 contact hole in printed circuit trace 21 and in refill oxide  
 18 and 23 an electronic component of the evaluation circuit.

100 denotes a micromechanical functional plane featuring a  
 15 movable sensor structure 10, here an acceleration sensor, 200  
 a covering plane for hermetically sealing movable sensor  
 structure 10, and 300 a printed circuit trace plane.

In this first example embodiment, which may be manufactured by  
 20 silicon surface micromachining which is conventional, covering  
 plane 200, features a monocrystalline region 14, which is  
 epitaxially grown on underlying monocrystalline region 7.  
 Covering plane 200 features polycrystalline region 15 which is  
 epitaxially grown on underlying polycrystalline starting layer  
 25 13 at the same time. Monocrystalline and polycrystalline  
 silicon is grown side by side in one process step.

Monocrystalline region 14 of covering plane 200 contains  
 integrated circuit elements of an evaluation circuit. A CMOS  
 30 transistor 23 is illustrated as an example.

Analogously, micromechanical functional plane 100 features  
 monocrystalline region 7 which is epitaxially grown on  
 underlying monocrystalline substrate region 1 and  
 35 polycrystalline region 8 which is epitaxially grown on  
 underlying polycrystalline starting layer 6 at the same time.  
 This process step of simultaneously growing Si in single- and

polycrystalline form is performed both for sensor structure 10 and for covering plane 200.

Micromechanical functional plane 100 features buried polysilicon layer 3 underneath movable sensor structure 10 as a wiring plane.

Figures 2a and b are schematic cross-sectional views of the manufacturing steps of the micromechanical component illustrated in Figure 1.

In general, IC processes require a single-crystalline Si substrate as a starting material for the process. This applies both to processes with analog components requiring an epitaxially deposited single-crystalline Si layer and pure CMOS processes not requiring epitaxy. In this example, therefore, one starts with a single-crystalline Si wafer as substrate 1.

In a first step, an oxidation of substrate 1 is performed to form lower oxide 2. Subsequently, buried polysilicon 3 is deposited and patterned as a lower printed circuit trace region. In a following step, sacrificial oxide 5 is deposited and patterned. Thereupon, a deposition and patterning of first starting polysilicon 6, in particular a removal of the starting polysilicon and of lower oxide 2 are performed at locations where single-crystalline silicon (region 7 illustrated in Figure 2a) is intended to grow on substrate 1 during the later epitaxy step.

After that, the epitaxy step is performed in which monocrystalline silicon region 7 is grown together with polycrystalline silicon region 8 of micromechanical functional plane 100. A further step is an optional planarization of the resulting structure to compensate for slight differences in height due to the substructure disposed between substrate 1 and polycrystalline silicon region 8.

Then, as illustrated in Figure 2b, a refilling is performed with refill oxide 11 as well as a patterning of refill oxide 11 to form contact holes 12. Subsequently, second starting polysilicon layer 13 is deposited and patterned together with first refill oxide 11, in particular, second starting polysilicon layer 13 and refill oxide 11 are removed at locations where single-crystalline silicon (region 14 illustrated in Figure 2b) is intended to grow on region 7. In a subsequent process step, the second epitaxial process follows in which monocrystalline silicon is deposited in region 14 and polycrystalline silicon is concurrently deposited in region 15. Again, optionally, a planarization of the resulting covering layer is performed to compensate for the substructure between polysilicon region 8 and polysilicon region 15.

Thereupon, trenches 17 which are used for insulation and as etch holes for removing first refill oxide 11 are formed in second epitaxial polysilicon 15. The etch profile of trenches 17 may be selected so that they widen downward as indicated in Figure 2b. The upper opening diameter may be selected to be minimal so that the deposition of second refill oxide 18 may be accomplished more quickly and, in fact, without a significant quantity of second refill oxide 18 getting into movable sensor structure 10. Thus, an anisotropic oxide deposition is desired and, to be more precise, only on the surface if possible.

In a subsequent process step, movable sensor structure 10 is etched free by removing lower oxide 2, sacrificial oxide 5 and first refill oxide 11 through etch trenches 17. For better control, it may also be possible to divide the etching free into two steps in that, prior to depositing first refill oxide 11, lower oxides 2 and 5 are removed and first refill oxide 11 is deposited. An important advantage of this process is that, during sacrificial layer etching, which is presently performed with HF vapor, no electronic circuit or aluminum are present

yet which, in the case of back-end processes, may be protected only with great difficulty and effort.

In the next step, second refill oxide 18 is deposited and patterned. A predetermined pressure is adjusted, and a predetermined gas atmosphere is adjusted during the final closing of the hollow spaces by second refill oxide 18, which determines the properties of the enclosed gas and consequently, inter alia, the attenuation of mechanical sensor structure 10.

Subsequent to the completion of the micromechanical component, the IC process, for example a CMOS or BiCMOS process, may be performed for manufacturing the evaluation circuit in monocrystalline silicon region 14. Thereupon, a deposition and patterning of printed circuit trace plane 300, in particular of oxide 19 and printed circuit trace aluminum 21 occur. To complete the component, usually, the chips are diced and an assembly is performed as with standard IC components.

Figure 3 is a schematic cross-sectional view of a micromechanical component according to a second example embodiment of the present invention.

As illustrated in Figure 3, in addition to the reference symbols already introduced, 24 denotes an SOI (Silicon on Insulator) layer and 25 an insulator layer. In this second example embodiment, substrate 1, insulator layer 25 and monocrystalline silicon layer 24 form an SOI structure which is conventional.

In the component, lower oxide 2, buried polysilicon 3, contact hole 4 in sacrificial oxide 5, sacrificial oxide 5, first starting polysilicon 6, first single-crystalline silicon of epitaxy 7, and first epitaxial polysilicon 8 are omitted.

Consequently, if such an SOI wafer is used as the starting material, then numerous process steps are omitted since then, the mechanically active structure is formed from SOI material 24. In this second example embodiment, the entire wiring is transferred into printed circuit trace plane 300.

Although the present invention has been described above in the light of example embodiments, it is not limited thereto but may be modified in many ways.

In particular, it is possible to use arbitrary micromechanical base materials such as germanium and not only the silicon substrate specified by way of example.

Also, it is possible to form arbitrary sensor structures and not only the illustrated acceleration sensor.

Region 15 does not necessarily have to be polycrystalline but may also be recrystallized or the like.

ABSTRACT

A micromechanical component includes: a substrate; a micromechanical functional plane provided on the substrate; a covering plane provided on the micromechanical functional plane; and a printed circuit trace plane provided on the covering plane. The covering plane includes a monocrystalline region which is epitaxially grown on an underlying monocrystalline region, and the covering plane includes a polycrystalline region which is epitaxially grown on an underlying polycrystalline starting layer at the same time.

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JC05 Rec'd PCT/PTO 1 1 DEC 2001

[10191/2083]

MICROMECHANICAL COMPONENT AND CORRESPONDING  
MANUFACTURING METHOD

[Background Information

] **FIELD OF THE INVENTION**

The present invention relates to a micromechanical component  
5 including a substrate, a micromechanical functional plane  
provided on the substrate, a covering plane provided on the  
micromechanical functional plane, and a printed circuit trace  
plane provided on the covering plane. The present invention  
also relates to a corresponding manufacturing method.

10 **BACKGROUND INFORMATION**

Micromechanical function will be understood as an arbitrary  
active function, for example a sensor function, or passive  
function, for example a printed circuit trace function.

15 Although applicable to arbitrary micromechanical components  
and structure, in particular to sensors and actuators, the  
present invention and its underlying problem will be explained  
with reference to a micromechanical component, for example an  
20 acceleration sensor, which is manufacturable in the technology  
of silicon surface micromachining.

[Generally known are monolithically] **Monolithically**  
integrated, surface-micromachined inertial sensors [whose]  
25 **with** movable structures [are] affixed to [the] **a** chip in an  
unprotected manner (analog devices) **are generally known**.

[Because of this,] **These designs cause** an increased  
expenditure of time and energy during handling and packaging[  
ensues].

30 [This problem] **These problems** can be avoided using a sensor  
having [the] **an** evaluation circuit on a separate chip; in this



context, for example, the surface-micromachined structures are covered by a second cap wafer. This type of packaging [creates] composes a high portion of the cost of a surface-micromachined acceleration sensor. This cost results from the large surface required for the sealing surface between the cap wafer and the sensor wafer and because of the complex patterning (2-3 masks, bulk micromachining) of the cap wafer.

The evaluation circuit is implemented on a second chip and connected to the sensor element via wire [bottom] bonding. This, in turn, creates the necessity for the sensor elements to be sized such that the parasitic effects developing due to the parasites in the lead wires and bonding wires are negligible[,] and that they no longer have any dominant influence on the sensor function. In addition, [flip-chips] flip-chip techniques [have to be] are ruled out because of parasitic effects.

Such sensors could [make do with] use considerably less surface for the micromechanics if the evaluation circuit were situated on the same Si chip and the sensitive electrodes could be connected with only low parasities.

German Published Patent Application [DE] No. 195 37 814 [A1] describes the structure of a functional layer system and a method for the hermetically packaging of surface-micromachined sensors. Explained in this context is the manufacture of the sensor structure using known technological methods. The mentioned hermetical packaging is effected using a separate cap wafer which is made of silicon and patterned using complex patterning processes such as KHO etching. The cap wafer is affixed to the substrate featuring the sensor (sensor wafer) using a glass solder (seal glass). For this purpose, a broad bonding frame is required around each sensor chip to ensure sufficient adhesion and tightness of the cap. This

considerably reduces the number of sensor chips per sensor wafer. Due to the large space required and the complex manufacture of the cap wafer, considerable costs are attributable to the sensor packaging.

5

German Published Patent Application [DE] No. 43 41 271 [A1 discloses] describes a micromechanical acceleration sensor whose components are composed partly of monocrystalline material and partly of polycrystalline material. For  
10 manufacturing this [known] micromechanical acceleration sensor, an epitaxial reactor is used. A starting layer made of LPCVD polysilicon is used for determining the regions where polycrystalline silicon is intended to grow during the epitaxial process.

15

[Advantages of the Invention

] SUMMARY

The micromechanical component [according to the present invention having the features of Claim 1] and the  
20 manufacturing method according to [Claim 9] the present invention have [the following] several advantages. It is possible for the evaluation circuit and the sensor element to be monolithically integrated on one chip. Error-prone complex bonding wires between the sensor element and the evaluation  
25 circuit [can] may be omitted. The size of the sensing elements [can] may be reduced since less parasitic effects occur in the bonding. Only one chip has to be mounted. The process is based on the surface-micromachining process [known from document P4318466.9] described in German Published Patent Application  
30 No. 43 18 466, which yields epitaxial polysilicon having a thickness of at least 10  $\mu\text{m}$ . A simplification of the surface-micromachining process [ensues] is provided because the structures [can] may be bonded from above. The buried polysilicon [can] may be omitted.

35

The integration of the component is independent of the process of the evaluation circuit to the greatest possible extent [as]. As a result [of which an], the adaptation to new IC processes is simplified. Depending on the sensor principle, the component [can] may be reduced to the size of the bonding pads heretofore required on the IC for bonding [as a result of which], which results in the cost [is] not [increased] increasing due to additional surface.

According to the present invention, the sensor chip [can] may be connected using the so-called "flip-chip method", that is upside down with eutectic or gold bumps instead of using bonding wires, since the parasitic influences are strongly reduced in comparison with the two-chip solution. Using this technique, it is also possible to produce sensors with CSP (chip scale package) [whosel], package of which is no more than 20% larger than the chip. A [CPS-packaged] CSP-packaged chip [can] may be premeasured and trimmed prior to assembly.

The core of the present invention is the combination of the single-crystalline and polycrystalline growth during the deposition of the covering layer in the epitaxial reactor. In the process, single-crystalline silicon requires a single-crystalline surface as a starting layer, polycrystalline silicon requires a polycrystalline starting layer which [is preferably] may be deposited using LPCVD.

[Advantageous refinements and improvements of the respective objective of the present invention can be found in the subclaims.]

According to [a preferred refinement] one example embodiment, a first layer featuring the micromechanical functional plane has a monocrystalline region which is epitaxially grown on the underlying monocrystalline region as well as a polycrystalline

region which is epitaxially grown on the underlying polycrystalline starting layer at the same time. Thus, the same epitaxial step is used twice in two different planes.

5 According to [a further preferred refinement] another example embodiment, a first layer featuring the micromechanical functional plane has an SOI-type monocrystalline region formed above an insulator layer with the substrate. This has the advantage that the buried polysilicon layer [can] may be  
10 omitted and that one epitaxial step is dropped. [Preferably used as silicon is a] A single-crystalline, high-doped base silicon material may be used which is free of mechanical stress.

15 According to another [preferred refinement] example embodiment, the monocrystalline region includes a second layer which is deposited on the first layer and which features one or a plurality of integrated circuit elements of an evaluation circuit or wiring elements. In this manner, a so-called  
20 "monolithically integrated one-chip solution" [can] may be attained.

According to [a further preferred] another example embodiment, the polycrystalline region of the micromechanical functional  
25 plane features a movable sensor structure.

According to [a further preferred refinement] another example embodiment, the micromechanical functional plane features a buried polysilicon layer underneath the movable sensor  
30 structure.

According to another [preferred refinement] example embodiment, one or a plurality of flip-chip connection elements, [preferably] e.g., gold bumps, are provided in the

printed circuit trace plane. This is a rugged bonding type which is made possible by the substantially planar surface.

According to [a further preferred] another example embodiment,  
5 the component [can] may be manufactured by silicon surface micromachining.

[Drawings

10 Exemplary embodiments of the present invention are depicted in the drawing and will be explained in greater detail in the following description.]

#### BRIEF DESCRIPTION OF THE DRAWINGS

15 Figure 1 [shows] is a schematic cross-sectional view of a micromechanical component according to a first example embodiment of the present invention[, ].

Figures 2a[, b depict a] and b are schematic cross-sectional  
20 [view] views of [a] the manufacturing steps of the micromechanical component [according to] illustrated in Figure 1[; and].

Figure 3 [shows] is a schematic cross-sectional view of a  
25 micromechanical component according to a second example embodiment of the present invention[, ].

[Description of the Exemplary Embodiments

#### ] DETAILED DESCRIPTION

30 In the Figures, identical or functionally identical components are denoted by the same reference symbols.

Figure 1 is a schematic cross-sectional view of a micromechanical component according to a first example  
35 embodiment of the present invention.

In Figure 1, 1 denotes a silicon substrate wafer, 2 a lower oxide, 3 buried polysilicon, 4 a contact hole in sacrificial oxide 5, 5 a sacrificial oxide, 6 a first starting polysilicon, 7 a first single-crystalline silicon of epitaxy, 8 a first epitaxial polysilicon, 9 an insulating trench, 10 a movable sensor structure, 11 a first refill oxide, 12 a contact hole in refill oxide 11, 13 a second starting polysilicon, 14 a second single-crystalline silicon of epitaxy, 15 a second epitaxial polysilicon, 16 an electrical and/or mechanical connecting element between the first and the second epitaxial polysilicon, 17 a trench, 18 a second refill oxide, 19 an oxide for insulating the printed circuit traces, 20 a cross connection, 21 a printed circuit trace, 22 a contact hole in printed circuit trace 21 and in refill oxide 18 and 23 an electronic component of the evaluation circuit.

100 denotes a micromechanical functional plane featuring a movable sensor structure 10, here an acceleration sensor, 200 a covering plane for hermetically sealing movable sensor structure 10, and 300 a printed circuit trace plane.

In this first example embodiment, which [can] may be manufactured by silicon surface micromachining which is [known per se] conventional, covering plane 200, [on one hand,] features a monocrystalline region 14, which is epitaxially grown on underlying monocrystalline region 7. [On the other hand, covering] Covering plane 200 features polycrystalline region 15 which is epitaxially grown on underlying polycrystalline starting layer 13 at the same time. [In other words, monocrystalline] Monocrystalline and polycrystalline silicon is grown side by side in one process step.

Monocrystalline region 14 of covering plane 200 contains integrated circuit elements of an evaluation circuit. A CMOS transistor 23 is illustrated as an example.

Analogously, micromechanical functional plane 100 features monocrystalline region 7 which is epitaxially grown on underlying monocrystalline substrate region 1 and polycrystalline region 8 which is epitaxially grown on underlying polycrystalline starting layer 6 at the same time. This process step of simultaneously growing Si in single- and polycrystalline form is [carried out] performed both for sensor structure 10 and for covering plane 200.

Micromechanical functional plane 100 features buried polysilicon layer 3 underneath movable sensor structure 10 as a wiring plane.

Figures 2a[,] and b [depict a] are schematic cross-sectional [view] views of [a] the manufacturing steps of the micromechanical component [according to] illustrated in Figure 1.

In general, IC processes require a single-crystalline Si substrate as a starting material for the process. This applies both to processes with analog components requiring an epitaxially deposited single-crystalline Si layer and pure CMOS processes not requiring epitaxy. In this example, therefore, one starts with a single-crystalline Si wafer as substrate 1.

In a first step, an oxidation of substrate 1 is [carried out] performed to form lower oxide 2. Subsequently, buried polysilicon 3 is deposited and patterned as a lower printed circuit trace region. In a following step, sacrificial oxide 5 is deposited and patterned. Thereupon, a deposition and patterning of first starting polysilicon 6, in particular a removal of the starting polysilicon and of lower oxide 2 are [carried out] performed at locations where single-crystalline silicon (region 7 illustrated in Figure 2a) is intended to grow on substrate 1 during the later epitaxy step.

After that, the epitaxy step is [carried out] performed in which monocrystalline silicon region 7 is grown together with polycrystalline silicon region 8 of micromechanical functional plane 100. A further step is an optional planarization of the resulting structure to compensate for slight differences in height due to the substructure [lying] disposed between substrate 1 and polycrystalline silicon region 8.

Then, as illustrated in Figure 2b, a refilling is [carried out] performed with refill oxide 11 as well as a patterning of refill oxide 11 to form contact holes 12. Subsequently, second starting polysilicon layer 13 is deposited and patterned together with first refill oxide 11, in particular, second starting polysilicon layer 13 and refill oxide 11 are removed at locations where single-crystalline silicon (region 14 illustrated in Figure 2b) is intended to grow on region 7. In a subsequent process step, the second epitaxial process follows in which monocrystalline silicon is deposited in region 14 and polycrystalline silicon is concurrently deposited in region 15. Again, optionally, a planarization of the resulting covering layer is [carried out] performed to compensate for the substructure between polysilicon region 8 and polysilicon region 15.

Thereupon, trenches 17 which are used for insulation and as etch holes for removing first refill oxide 11 are formed in second epitaxial polysilicon 15. The etch profile of trenches 17 [can] may be selected [in such a manner] so that they widen downward as indicated in Figure 2b. The upper opening diameter [should] may be selected to be minimal so that the deposition of second refill oxide 18 [can] may be accomplished more quickly and, in fact, without a significant quantity of second refill oxide 18 getting into movable sensor structure 10. Thus, an anisotropic oxide deposition is desired and, to be more precise, only on the surface if possible.



In a subsequent process step, movable sensor structure 10 is etched free by removing lower oxide 2, sacrificial oxide 5 and first refill oxide 11 through etch trenches 17. For better control, it [would] may also be possible to divide the etching free into two steps in that, prior to depositing first refill oxide 11, lower oxides 2 and 5 are removed and first refill oxide 11 is deposited [only then]. An important advantage of this process [lies in] is that, during sacrificial layer etching, which is presently [carried out] performed with HF vapor, no electronic circuit or aluminum are present yet which, in the case of back-end processes, [can] may be protected only with great difficulty and effort.

In the next step, second refill oxide 18 is deposited and patterned[, a]. A predetermined pressure is adjusted, and a predetermined gas atmosphere is adjusted during the final closing of the hollow spaces by second refill oxide 18, which determines the properties of the enclosed gas and consequently, inter alia, the attenuation of mechanical sensor structure 10.

Subsequent to the completion of the micromechanical component, the IC process, for example a CMOS or BiCMOS process, [can now] may be [carried out] performed for manufacturing the evaluation circuit in monocrystalline silicon region 14. Thereupon, a deposition and patterning of printed circuit trace plane 300, in particular of oxide 19 and printed circuit trace aluminum 21 [take place] occur. To complete the component, usually, the chips are diced and an assembly is [carried out] performed as with standard IC components.

Figure 3 is a schematic cross-sectional view of a micromechanical component according to a second example embodiment of the present invention.

[In] As illustrated in Figure 3, in addition to the reference symbols already introduced, 24 denotes an SOI (Silicon on Insulator) layer and 25 an insulator layer. In this second example embodiment[, thus], substrate 1, insulator layer 25 and monocrystalline silicon layer 24 form an SOI structure which is [known per se] conventional.

In the [so designed] component, lower oxide 2, buried polysilicon 3, contact hole 4 in sacrificial oxide 5, sacrificial oxide 5, first starting polysilicon 6, first single-crystalline silicon of epitaxy 7, and first epitaxial polysilicon 8 are omitted.

Consequently, if such an SOI wafer is used as the starting material, then numerous process steps are [dropped] omitted since then, the mechanically active structure is formed from SOI material 24. In this second example embodiment[, thus], the entire wiring is transferred into printed circuit trace plane 300.

Although the present invention has been described above in the light of [preferred exemplary embodiment] example embodiments, it is not limited thereto but [can] may be modified in many ways.

In particular, it is possible to use arbitrary micromechanical base materials such as germanium and not only the silicon substrate specified by way of example.

Also, it is possible to form arbitrary sensor structures and not only the illustrated acceleration sensor.

Region 15 does not necessarily have to be polycrystalline but [can] may also be recrystallized or the like.

[Abstract

] **ABSTRACT**

[The present invention provides a] **A** micromechanical component  
 [including] **includes:** a substrate [(1)]; a micromechanical  
 5 functional plane [(100)] provided on the substrate; a covering  
 plane [(200)] provided on the micromechanical functional plane  
 [(100)]; and a printed circuit trace plane [(300)] provided on  
 the covering plane [(200)]. The covering plane [(200)  
 features] **includes** a monocrystalline region [(14)] which is  
 10 epitaxially grown on an underlying monocrystalline region [(7;  
 24)]; and the covering plane [(200) features] **includes** a  
 polycrystalline region [(15)] which is epitaxially grown on an  
 underlying polycrystalline starting layer [(13)] at the same  
 time. [

(Figure 1)]